MODELING EPISODIC RELEASE OF ^{40}AR RELEASE FROM THE MOON WITH IMPLICATIONS FOR THE AR ATMOSPHERE OF MERCURY T. H. Morgan[1] and R. M. Killen[2], [1] Instrumentation and Space Science Division, Southwest Research Institute, P. O. Drawer 28510, San Antonio, Texas, 78228-0510, tom@image1.space.swri.edu,, [2] Instrumentation and Space Science Division, Southwest Research Institute, P. O. Drawer 28510, San Antonio, Texas, 78228-0510, rosemary@whipple.space.swri.edu..

The Apollo 17 lunar surface mass spectrometer detected an Ar atmosphere about the Moon. The instrument was able to observe the atmosphere for slightly more than half of each lunation over a period of almost a year. Hodges and his coworkers (1-3) have argued that the rate of supply of ^{40}Ar to the atmosphere at some epochs approaches 3 x 10^{20} atoms s^{-1} (about 1% of the current global production rate of ^{40}Ar throughout the entire lunar volume) and is variable over a time scale of less than a year. They further argued that the variations in the supply showed some correlation to moonquake activity.

Several hypotheses have been advanced for a correlation between the moonquakes and the Ar releases. Hodges and Hoffman favor deep release due to internal movements which periodically open paths to the lunar surface for gas filled voids which are, in turn, supplied from even greater depths. It can be argued that the total pore volume within the regolith is much larger than the connected pore volume, and that very modest disturbances could easily bring large volumes of hitherto unconnected pore space into the system. Here we report on an effort to model the diffusion of ^{40}Ar through the Lunar regolith and determine whether the a sudden release of ^{40}Ar at depth could reach the atmosphere rapidly, and to relate the volume of gas released to the surface supply rate. The various initial conditions are chosen to, at least approximately match the possible solutions which have been put forward for these results.

We have solved Knudsen diffusion numerically for archetype initial conditions which reflect the various hypotheses available for the deep release of ^{40}Ar. The coefficient for Knudsen diffusion is a function of the following: 1) the gas-surface interaction between the ^{40}Ar and the pore walls for which there is relevant laboratory data (4); 2) the average pore size; 3) the average connected pore and microcrack volume; 4) the pore and microcrack geometry; 5) and the temperature of the gas. Items 2 through 4 above are functions of depth. Further, the average pore size and average connected pore volume determine the surface area at a given depth, which in turn, controls the source of new species from the surface. The upward boundary condition we have used is the evaporative boundary condition; $[D\partial n/\partial z]_{surface} = An_{surface}$ where n is the density and D is the density. We have used two lower boundary conditions: 1) that there is no flow at the lower regolith boundary (the depth where the pressure is sufficient to seal microcracks and fractures); and 2) that there is a flow initiated at that depth at t=0. A variety of initial gas densities were examined.

The numerical solution was done using a Crank-Nicholson differencing scheme which is stable even for large time steps. This is necessary because at the upper boundary the steps in z(depth) and t(time) must be such that $\{D/(\Delta z)^2 + A/z\}\Delta t$ does not grow large. The form of the iteration is

$$u_j^+ - u_j =$$

$$\Gamma D_{+1/2} \{(u_{j+1}^+ + u_{j+1}) - (u_j^+ + u_j)\} -$$

$$\Gamma D_{-1/2} \{(u_j^+ + u_j) - (u_{j-1}^+ + u_{j-1})\}$$

where

$$\Gamma = \Delta t/(\Delta z^2).$$

While the results are quite varied and depend on the initial conditions assumed, we can generalize to say that a good figure of merit for the time required to see a disturbance at depth L at the surface is of order $L^2/4D_{ave}$, where D_{ave} is the average diffusion rate over the upper crust from L to the surface, and the maximum rate is of order $n_0 D_{ave}/L$. The practical effect of this is to require release at shallow depths (depths for which the average temperature is well below the closure temperature) if we are to explain the short time variation. However, the average source of ^{40}Ar required to maintain the Ar atmosphere can be achieved by diffusion through the crust.

On a broader level, these results can be used to place some bounds on the likely ^{40}Ar supply to the atmosphere of Mercury. On other inner planets (5 and references therein), the relative abundance of the noble gases and their isotopes has proven very useful to understanding the formation and evolution of the planet. That both significant ^{40}Ar and He derived from the crust are present seems to be assured. Mariner 10 measured He, but unfortunately, only a very generous upper limit was placed on the other noble gases (6,7). The estimation of an ^{40}Ar abundance for Mercury will be highly model dependent, because the abundance of K and the distribution of K in the crust is completely unknown. In addition, the magnetic field may serve to greatly increase the ^{40}Ar. atmosphere by returning a large fraction of ^{40}Ar photo-ions, depending in part on the possible electric fields present at or near the surface.

1. Hoffman *et al*., 1973, NASA SP-330, P 17-1..2. Hodges, R. R., and J. H. Hoffman, 1974. Proc. Lunar Plan Sci Conf 5th, 2955. 3. Hodges, R. R., The Moon, 14, 139. 4. Bernatowicz, T. J., and F. A. Podesek, 1991, Proc. Lunar Plan Sci Conf 21th, 307. 5. Harper, C. L., and S. B. Jacobsen, 1966, Science, 273, 1814.. 6. Broadfoot, A. L., D. E. Shemansky, and S. Kumar, 1976, Geophys. Res. Lett., 3, 578. 7. Hunten, D. M., T. H., Morgan, and D. E. Shemansky, 1988, In Mercury(Vilas *et al.* eds.), 562.